IRCF REPTILES & AMPHIBIANS
CONSERVATION AND NATURAL HISTORY

Non-overlapping Distributions of Feral Sheep (*Ovis aries*) and Stout Iguanas (*Cyclura pinguis*) on Guana Island, British Virgin Islands

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Abstract.—Stout Iguanas (*Cyclura pinguis*) remain one of the most critically endangered reptiles in the world. Factors contributing to that status include habitat loss, predation by introduced species, and competition with introduced herbivores. On Guana Island, British Virgin Islands, the presence of feral sheep (*Ovis aries*) has been a hypothesized detriment to iguanas. Using motion sensitive cameras, we documented the distribution of feral sheep on Guana Island in 2010. We also quantified the impact of feral sheep on ground vegetation by comparing plant abundance at long-term sheep exclosures and areas where sheep were absent to areas where sheep were present. Finally, we compared sheep distribution to iguana distribution on the island. The co-occurrence of sheep and Stout Iguanas was less than expected, indicating possible competition. Although we detected no difference in vegetative cover between areas where sheep were present and absent, the long-term exclosures showed that the exclusion of sheep allowed the abundance of many plant species to increase. Our data support the hypothesis that feral sheep are altering the abundance of ground-level vegetation and limiting iguana distribution on the island.

Five principal factors contribute to species endangerment: Natural causes, over-hunting, introduced predators, non-predatory invasives, and habitat alteration (Fisher et al. 1969). Hunting, predator introduction, and habitat alteration have received considerable attention in both the popular and scientific press. The more subtle but no less profound effects of non-predatory invasive species such as herbivores have received less attention. Introduced herbivores may outcompete native species for resources or negatively affect them by altering the habitat (Lowney et al. 2005). Herbivorous reptiles appear to be particularly sensitive to the effects of introduced herbivorous mammals. As an example, Cuban Ground Iguanas (*Cyclura nubila*) now compete with deer (*Odocoileus* spp.) and feral goats (*Capra hircus*) at Guantanamo Bay, Cuba (Roca and Sedaghatkish 1998). That competition forced iguanas to move farther while foraging and juveniles to disperse greater distances and suffer greater mortality. Similarly, Stout Iguanas (*C. pinguis*) altered their diet and declined in numbers in response to feral livestock grazing on Anegada Island, British Virgin Islands (BVI; Mitchell 1999). Feral livestock

Fig. 1. The distribution of Stout Iguanas (*Cyclura pinguis*) and feral sheep on Guana Island (British Virgin Islands) is largely disjunct. Photograph by Robert Powell.

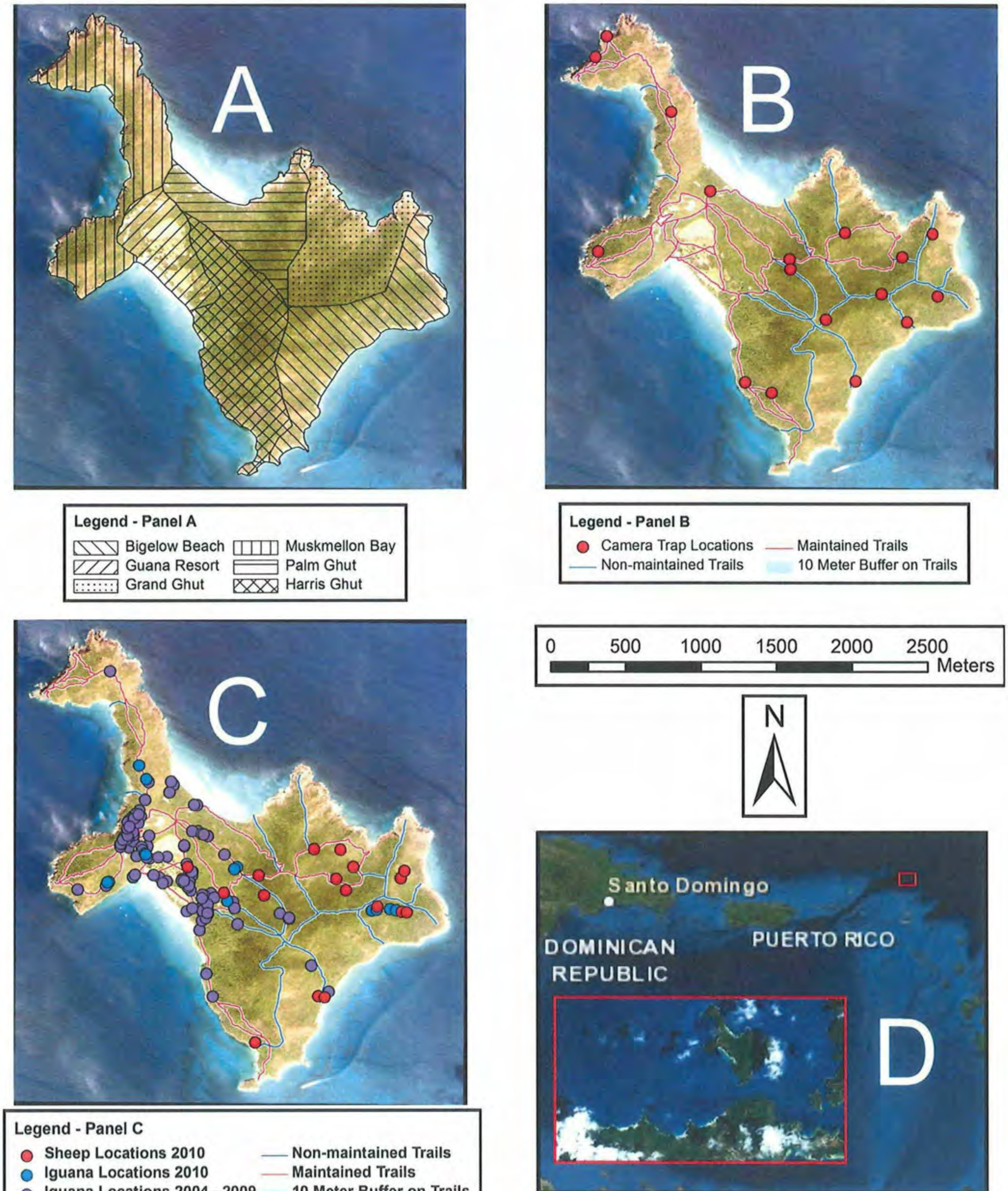

Fig. 2. Sampling effort of: (A) Subdivision of Guana Island into 6 units; (B) locations of cameras traps (red dots) along the trail system (red = maintained trails, blue = non-maintained trails, light blue = 10 m buffer of all trails) of Guana Island; (C) 2010 locations of encountered sheep (red dots), 2010 locations of encountered iguanas (blue dots), 2004–2009 locations of iguanas; (D) location of Guana Island within the greater Caribbean region. Note: scale bar for figures A, B, and C only.

Table 1. Ground cover composition at locations where sheep were and were not detected. "Green vegetation" represents pooling of all living plant material.

		Mean ± SD*	n**	%***
Sheep Absent	Green Vegetation	1.05 ± 3.55	25	4
	Litter	73.76 ± 18.56	25	74
	Rock and Soil	15.60 ± 15.60	25	22
Sheep Present	Green Vegetation	2.93 ± 7.69	50	12
	Litter	73.64 ± 14.43	50	74
	Rock and Soil	7.32 ± 9.33	50	14

* Mean ± SD of encounters of each ground cover type per 100 sample points.

** Number of forest floor photos analyzed. Each photo had 100 sample points.

*** Percentage of cover type with all samples pooled.

also has been shown to be responsible for negative effects on other species of rock iguanas (Lemm and Alberts 2012).

The Stout Iguana is listed as Critically Endangered and Endangered by the IUCN (2004) and the U.S. Fish and Wildlife Service (1999), respectively. By the 1980s, Stout Iguanas were known to occur only on Anegada Island, where they were in rapid decline (Mitchell 1999). Concern for the species' persistence prompted the translocation of eight individuals from Anegada to Guana Island, BVI. A decade later, Goodyear and Lazell (1994) found that the Guana population (Fig. 1) was persisting, but had not achieved an island-wide distribution. Goodyear and Lazell (1994) suggested that competition with feral sheep (*Ovis aries*), still found on Guana Island despite several eradication attempts (Lazell 2005), might have been the cause of the limited expansion by Stout Iguanas. The iguana population has grown considerably (Perry and Mitchell 2003), but a disjunction between Stout Iguana and sheep distributions appears to remain (Anderson et al. 2010). Further, previous researchers have noted the existence of a browse line where sheep are common (G. Perry and C. Boal, pers. obs.). Nonetheless, no concerted effort has previously been made to compare the distributions of the iguana and sheep on the island. We therefore sought to quantify the distribution of both Stout Iguanas and feral sheep on Guana Island to determine if the two species' distributions are indeed non-overlapping. In addition, we sought to quantify the impacts of sheep browsing on island vegetation. Effects of sheep on the vegetation would provide a mechanistic explanation to support the hypothesis that feral sheep are negatively influencing iguana distributions.

Methods

Guana Island is a privately owned 340-ha island located less than 1 km north of Tortola, BVI (Fig. 2D). The island functions as a resort, although much of it is undeveloped, mostly free of human disturbance, and covered in dry tropical forest. Lazell (2005) provided a detailed overview of the island's natural history.

We subdivided Guana Island into six units (Fig. 2A) using ArcGIS 9.2 (ESRI 2006, Redlands, California). Four of the six units (Bigelow Beach, Grand Ghut, Harris Ghut, and Palm Ghut) are natural watersheds. The Guana Resort was defined as the area of the island receiving heavy human traffic. The remainder of the island was pooled into the Muskmellon Bay unit. We created a digital model of Guana Island consisting of 309 100 x 100-m grid cells (Fig. 3A). Steep terrain prevented us from sampling 168 of the 309 grid cells (Fig. 3B), and we do not consider these areas further. Based on field observations (see below), each grid cell was coded as having sheep, iguanas, neither, or both. The amount of overlap between sheep and iguanas was determined by comparing the number of grid cells with occurrence of both species to what would be expected (i.e., joint probability) from the portion of cells occupied by sheep and by iguanas.

We used seventeen motion sensitive cameras (Reconyx model RM30, Holmen, Wisconsin) to passively sample feral sheep and Stout Iguanas. In October 2010, within 10 m of the existing trail system of the island (Fig. 2B), we used a random number generator to determine possible camera placements. The number of camera locations placed in each of the six pre-determined units was determined by the relative size of each unit: Bigelow Beach, Grand Ghut, and Muskmellon Bay each received four cameras, Palm Ghut received three cameras, and Harris Ghut received two cameras (Fig. 2B). We did not place any cameras within the Guana Resort unit, as island staff informed us that the level of human traffic precludes the occurrence of sheep. Cameras were attached to trees 1 m above ground, orientated to provide the least

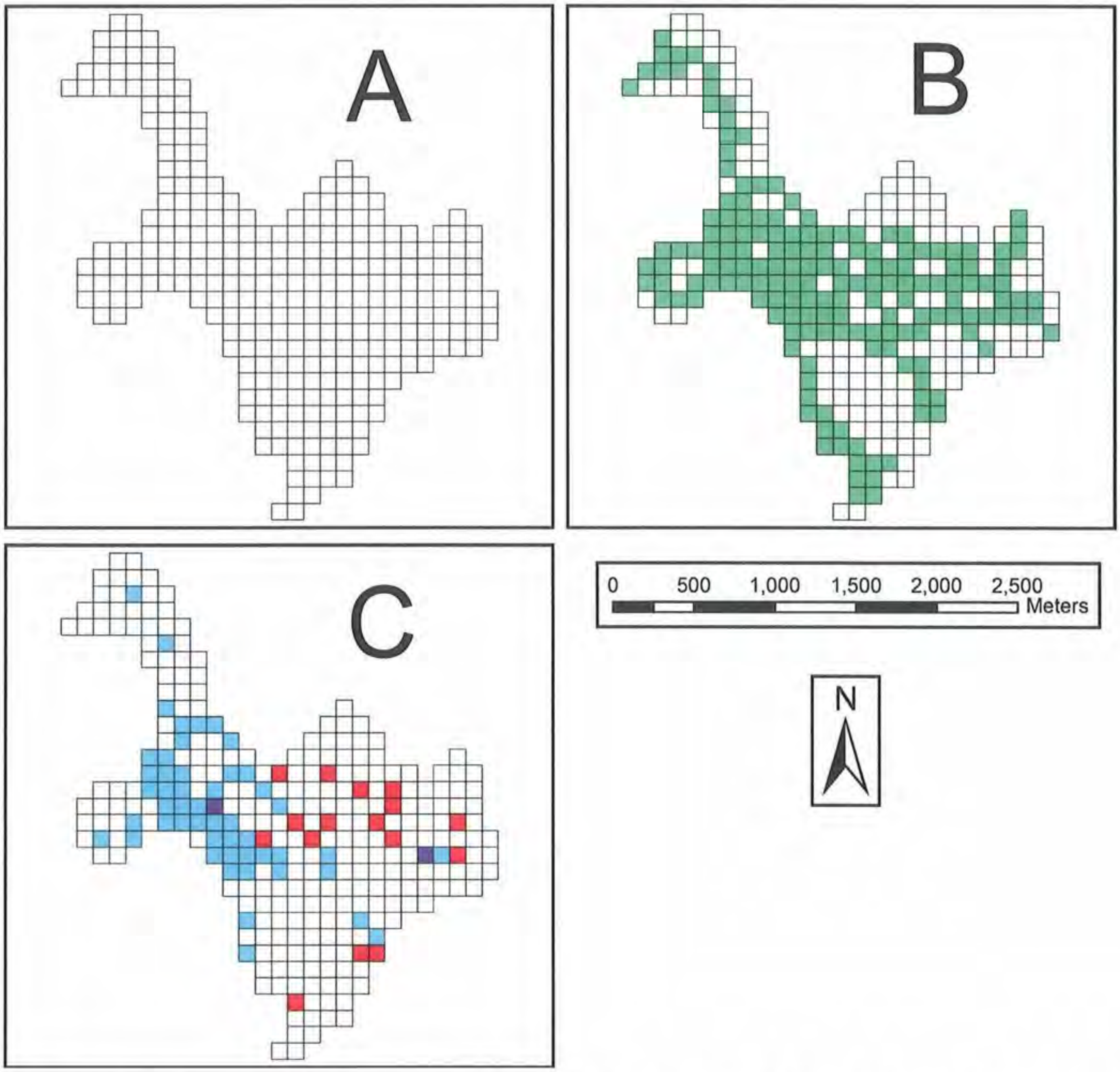

Fig. 3. (A) Subdivision of Guana Island into 309 100 x 100 m cells; (B) sampled cells (green); (C) sampled cells containing sheep (red), iguanas (blue), and sheep and iguanas (purple).

obstructed view, and programmed to record for three days. They then were moved to a new, pre-determined location. Additionally, we recorded the locations of chance encounters of sheep and iguanas during repeated hikes throughout the island. Indirect evidence of sheep presence, such as scat and sound, also were recorded. For iguana distributions, we incorporated all 159 previously recorded (2004–2009) locations (G. Perry, unpubl. data).

We assessed vegetation density by measuring vertical vegetative visual obstruction (hereafter, visual obstruction) at camera-trap locations. Using a 1-m Robel pole (Robel et al. 1970) segmented into 10-cm bands, we recorded visual obstruction at a distance of 1.8 m from the pole in each of the cardinal directions to the nearest 25%. To quantify ground cover, we took digital photographs of the forest floor at the pole location and 1.8 m from it in each of the cardinal directions. Photographs were taken from a height of 1 m. We analyzed photographs using SamplePoint (Booth et al. 2006), which superimposes 100 regularly spaced points on each photograph. At each point we recorded the cover type: Vegetation, litter, or open soil/rock. Wet conditions, such as those experienced by the BVI in the months just before

Table 2. Common plant species inside and outside of exclosures on Guana Island.

Species*	Common name**	Family	Growth habit***
Amyris elemifera	Sea Torchwood	Rutaceae	TR/SH
Bursera simaruba	Gumbo Limbo	Burseraceae	TR/SH
Capparis spp.	Caper	Capparaceae	TR/SH
Eugenia spp.	—	Myrtaceae	TR/SH
Guapira fragrans	Black Mampoo	Nyctaginaceae	TR/SH
Krugiodendron ferreum	Leadwood	Rhamnaceae	TR/SH
Macfadyena unguis-cati	Catclaw Vine	Bignoniaceae	VI
Opuntia repens	Roving Pricklypear	Cactaceae	SS/SH
Tragia volubilis	Fireman	Euphorbiaceae	VI/FB

* Taxonomy from Lazell (2005)

** Common names from USDA NRCS (2013)

*** Growth habit from USDA, NRCS (2013). FB = forb/herb, SH = shrub, SS = subshrub, TR = tree, VI = vine

our study (G. Perry, unpubl. data), can produce high plant densities regardless of browsing by feral sheep. Additionally, sheep are likely to be attracted to locations where vegetation is available. Thus, simple comparisons of locations with and without sheep could provide uninformative results. We therefore supplemented our findings with numbers obtained from two fenced sheep exclosures on the island and their paired, un-fenced control sites. These exclosures were established in 1997–98 and the abundance of nine plant species was measured following establishment and again in 2004 and 2010 (Table 2). They thus provide a long-term comparison of how sheep could be affecting the vegetation.

We used chi-square tests (Zar 2010) to examine differences between ground cover where sheep were present and absent. To examine differences in visual obstruction, we used *t*-tests to compare values recorded at each 10-cm band of the Robel pole in areas where sheep were present to the corresponding segment where sheep were absent. All statistical analyses were performed with R 2.13.0 (R Development Core Team 2011).

Results

Our cameras recorded sheep at five locations and a single iguana at one location (Fig. 2C). During hiking, we encountered sheep and iguanas (Figs. 4–6) at 12 and 53 other locations, respectively. Of the 168 grid cells sampled, we detected iguanas only in 28.6% (n = 48) of cells, we detected sheep only in 9.5% (n = 16) of cells, and we detected both iguanas and sheep in 1.2% (n = 2) of cells (Fig. 3C). Neither we nor previous researchers detected iguanas within the Grand Ghut watershed, which had the greatest number of sheep detections (Fig. 2C). The observed co-occurrence of iguanas and sheep was less than half the value expected based on the probabilities of sighting either species (2.7% or 5 cells).

At camera-trap locations, ground cover differed significantly between areas where sheep were and were not detected ($\chi^2 = 187.16$, df = 2, $p < 0.001$). The litter component of ground cover did not vary between areas where sheep were and were not detected, but the proportion of green vegetation and rock and soil did, with a greater percentage of green vegetation being observed in areas where sheep were detected (Table 1). Visual obstruction did not significantly differ between locations where sheep were and were not detected by cameras (Fig. 7; $p > 0.05$ in all cases).

Of the nine woody and herbaceous plants monitored in and outside of the exclosures, four species (*Amyris elmifolia*,

Fig. 4. Feral sheep were most often detected by camera traps at night and only on the eastern side of the island.

Fig. 5. Immature Stout Iguanas were most commonly encountered near the Guana Resort. This individual was marked with white paint to facilitate identification during a concurrent study. Photograph by Ben Skipper.

Bursera simarubra, *Capparis* spp., and *Tragia volubilis*) clearly increased in abundance when sheep were excluded (Fig. 8). Two other species (*Krugiodendron ferreum* and *Macfadyena unguis-cacti*) displayed stronger increases in abundance inside exclosures compared to outside, although some overlap in standard deviations exists (Fig. 8). *Eugenia* spp. and *Guapira fragrans* abundance seemed less affected by the exclosures, although trends show both increasing inside the exclosures (Fig. 8). One species, *Opuntia repens*, remained approximately stable over the 10-year observation period inside the exclosures, but declined sharply outside of exclosures. No monitored species declined in the exclosures when compared to control plots.

Discussion

Since their re-introduction almost 30 years ago, Stout Iguanas have established a self-sustaining population on Guana Island (Goodyear and Lazell 1994, Perry and Mitchell 2003, Anderson et al. 2010). However, prior researchers (Goodyear and Lazell 1994, Anderson et al. 2010) hypothesized that competition with feral sheep for available browse may limit iguana distribution on the island. Our data support this hypothesis. Iguanas and sheep are much less likely to co-occur than would be expected, suggesting that occurrence of sheep in some of the eastern portions of the island precludes iguana presence. We did encounter several iguanas (both adults and juveniles) at the eastern end of the island, where they had not previously been seen. We believe this represents a wider search effort, but it could represent an expansion of the population compared to the surveys of Goodyear and Lazell (1994) and Anderson et al. (2010).

A possible explanation for the lack of overlap between iguanas and sheep, consistent with Mitchell's (1999) observations on Anegada and studies of other species in the genus

Fig. 6. Large, mature Stout Iguanas were rarely encountered far from the Guana Resort. Photograph by Rebecca Perkins.

Cyclura (Lemm and Alberts 2012), is reduction in available forage for iguanas due to browsing by feral sheep. Although previous researchers (W. Anderson, pers. comm.) have observed a prominent browse line in areas occupied by sheep, we detected no difference in visual obstruction between areas with and without sheep detections. Possibly, the 1.8-m distance from which we recorded visual obstruction was insufficient to assess accurately the effects of browsing. More importantly, perhaps, Guana Island received above-average precipitation in the months before our study (G. Perry, pers. obs.), which could have allowed the vegetation to recover from browsing pressure. Guana Island experienced drought in 2009, which could have rendered the effects of browsing more pronounced, whereas in 2010, high rainfall may have rendered signs of browsing unobservable. Consistent with that interpretation, browse damage was obvious again in 2011, another dry year (G. Perry, pers. comm.).

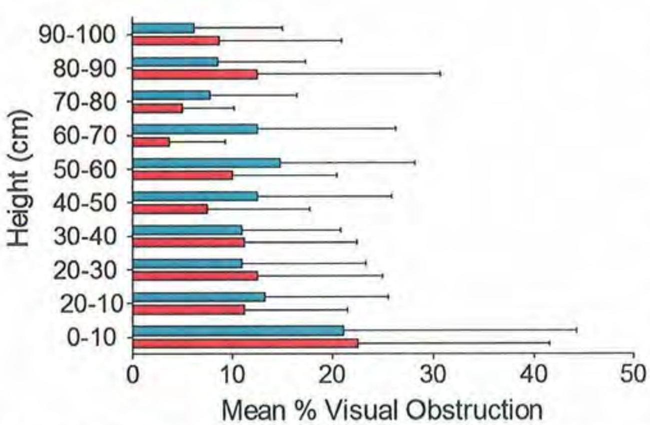

Fig. 7. Mean (± SD) percent visual obstruction measured of vegetation at camera trap locations, red bars indicate camera trap locations where sheep were detected; blue bars indicate areas where sheep were not detected.

We did not find differences in visual obstruction between camera-trap locations where sheep were and were not documented. Somewhat counterintuitive is that camera-trap locations where sheep were detected had a greater proportion of green vegetation than those where sheep were not detected. However, such differences might not be unexpected for two reasons. First, our study was conducted during a wet spell, when vegetation is relatively lush and regrowth is rapid. Second, sheep are likely to be attracted to available forage or avoid areas denuded of vegetation, and thus may preferentially be found at locations with more remaining vegetation. Our comparisons of sheep exclosures to un-enclosed control

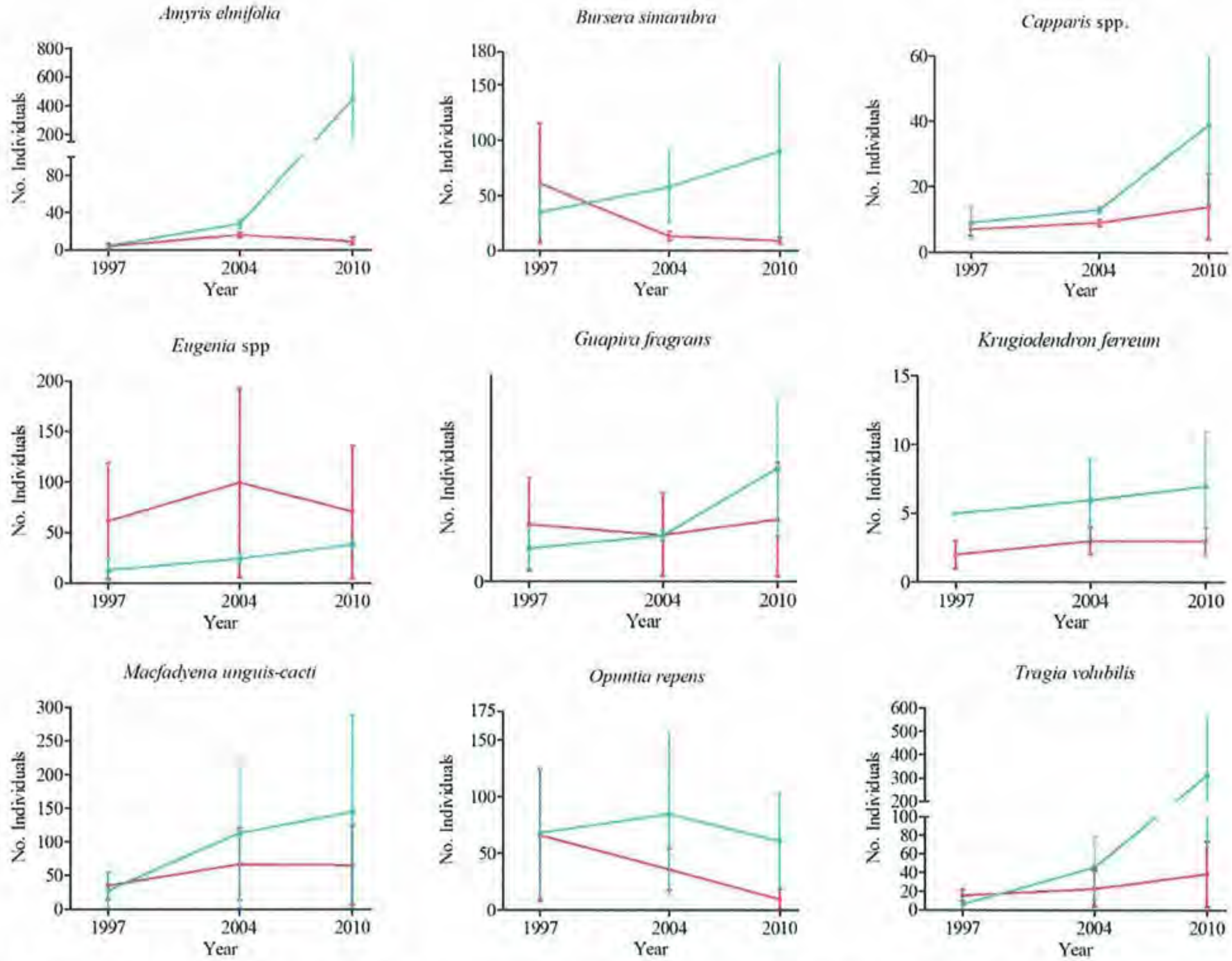

Fig. 8. Mean (± SD) number of individuals of nine plant species monitored from 1997/1998 to 2010. Blue lines represent plants within exclosures. Red lines represent plants outside of exclosures.

plots provided further evidence. We saw marked increases in four plant species, weaker increasing trends in another four species, and no declines inside exclosures.

Our study supports previous suspicions (Goodyear and Lazell 1994, Anderson et al. 2010) that feral sheep limit the distribution of Stout Iguanas on Guana Island. This is a source of concern, as the Guana population is one of the largest populations of the species and its survival may be critical to the long-term existence of *C. pinguis*. Although our short-term assessment of vegetation (assessments at camera-trap locations) did not reveal clear differences in vegetative structure in areas where sheep were and were not detected, assessments at the long-term exclosures did indicate that exclusion of sheep can have a positive effect on the vegetative community. Further exclusion of feral sheep through removal would likely be beneficial to Stout Iguanas by providing an opportunity for more complete expansion of the current distribution into the eastern half of the island. Sheep removal also could be of value to the island's vegetation, some of which is of significant conservation value (Procter and Fleming 1999, Lazell 2005). Other species that depend on the vegetation, such as invertebrates and birds, also could be affected positively by such management practices.

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